GROUP AND INDIVIDUAL REARING OF FIELD CRICKETS (ORTHOPTERA: GRYLLIDAE)[1,2]

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ABSTRACT: Groups of ca. 50 field cricket hatchlings, *Gryllus* spp., produce 20-40 adults when reared in gallon jars provisioned with water, Purina Cricket Chow®, and a sand substrate. *Gryllus rubens* hatchlings can be reared singly in 1-oz cups on a pintobean diet developed for cabbage loopers. This is the first account of a method suited to rearing large numbers of crickets singly; survivorship is high. Other cricket researchers report a variety of methods and diets that are useful in group rearing species of *Gryllus* and related genera.

Field crickets (Gryllinae, especially *Gryllus* spp.) have many advantages for use in field and laboratory studies of insect ecology and behavior. They are widely distributed, easily collected, large in size, easily sexed, can endure much handling, and have surfaces that permit easy marking for individual or group recognition. Moreover, they can be reared in groups of ca. 50 or singly at modest cost in money, labor, and space. The group-rearing method reported here has been used and improved during studies of southeastern *Gryllus* starting in 1970 (e.g., Walker 1974, 1980, 1987; Wineriter and Walker 1984; Walker and Sivinski 1986). The single rearing method was developed in order to eliminate social effects in experiments on the genetic and environmental determinants of wing dimorphism in *Gryllus rubens* (Walker 1987).

Group rearing methods developed by other researchers and used with *Gryllus* spp. and related crickets are summarized in Appendices A (personal communications) and B (published accounts).

Group Rearing

General. One-gallon (ca. 4 liters), wide-mouth glass jars serve as rearing containers. The jars are economical because they are mass-produced for food processors; their proportions make it difficult for crickets to leap out when the lids are off.

Approximately 900 ml of heat-sterilized, dry, fine sand is placed in the bottom of a jar and made to slope at 20-30 degrees (Fig. 1A). The sand at the lower elevation is then moistened with 50-60 ml of water establishing a gradient of moisture from damp sand on the lower elevation to dry sand on

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the higher elevation. The wetter area provides suitable sites for oviposition and maintains a favorable humidity within the jar. The drier area provides a favorable site for a food dish.

Next, a water vial (Fig. 1B) is pushed slightly into the moistened sand. The wet tip must not contact the sand or the water will be drawn out. Also, a polystyrene disposable weighing boat, 40x40 mm, or one-half of a plastic petri dish, 60x15 mm, of food (diet discussed below) is placed in the drier area (to slow molding). Size of the food container and amount of food depends on the number and size of crickets being reared. The weighing boat is adequate for smaller crickets while the petri dish is better for larger crickets. The container should hold enough food to last a little more than one week.

Finally, crickets are added — either a mated female is placed in the jar to lay eggs, then removed at or before first hatch (approximately 3 weeks), or 50 hatchlings from another oviposition container are placed in the jar. When the juveniles become larger, a perch is added to provide more space (Fig. 1A). The jar is capped with a plastic lid that has a 9 cm diameter hole for air circulation (Fig. 1A). A 10 cm diameter piece of wire cloth epoxyed to the lower surface of the lid prevents escapes of crickets and entry of flies, ants, and spiders. If a higher humidity within the jar is required, a circular cardboard or plastic disc with a hole less than 9 cm in diameter can be placed inside the lid. Reducing the area of the hole less than 50% is not recommended as this may cause the food to mold quickly. The jars are maintained in a rearing room or outdoors under a plywood roof. Under our usual laboratory conditions, 25°C and 16L:8D, most field crickets mature in approximately 4 months.

The jars of crickets are tended weekly. The food dish is changed and new food added. (If left longer, food will mold.) A wash bottle is used to remoisten the sand while maintaining the moisture gradient. The water vial requires filling no more than monthly if at all. The food dish and the water vial and its stopper are reused after washing with water and soaking 24 h in a 5-10% bleach solution for disinfection.

For most species, most of the time, we expect 20-40 adult crickets from a jar started with 50 hatchlings. Starting more than 50 hatchlings per jar usually does not change the outcome. Note, furthermore, that extra hatchlings do not have to be removed from a jar, i.e., oviposition jar, unless knowing the number started is important. Mortality is higher in crowded jars, but 20-40 full-sized adults can still be expected.

Diet. Finding a nutritionally adequate diet for grylline crickets is generally no problem. Foods used by other researchers for laboratory rearing of *Acheta* and *Gryllus* include Purina Cat Chow® and lettuce (Harrison 1979, Roff 1986), Purina Cat and Rabbit Chows® (Roff 1986),

chicken mash (Stout *et al.* 1976), and lettuce and dog biscuits (Weber *et al.* 1981). For many years, we used Purina Dog Chow®, finely ground for small nymphs and whole for larger nymphs and adults, and successfully reared at least eight species of *Gryllus* for one to eight generations. However, on three occasions we had greatly reduced survivorship in *G. rubens* beyond the second laboratory generation. Upon the third occasion, we inquired about alternative foods and learned that Purina sold another product wholesale to commercial rearers of bait crickets — viz., Cricket Chow®. We switched to Cricket Chow and survival of lab-reared *rubens* returned to its earlier levels for several generations, then began to decline again.

Because of this recurring problem with rearing *rubens,* we decided to test effects of three diets on the survivorship and rate of development of two genetic lines: F_1 hatchlings of field-collected *rubens* and F_{11} hatchlings of short-wing selected *rubens* (Walker 1987). The diets were newly purchased Purina Dog Chow, freezer-stored Purina Cricket Chow (purchased 2 years previously), and refrigerator-stored Cricket Chow (purchased 2 years previously). Five groups of 50 crickets each were started for each treatment in the F_1 line or 250 crickets per treatment. Due to a shortage of F_{11} crickets, three groups of 50, one group of 40, and one group of 32 crickets or 222 per treatment were started. Results are summarized in Table 1.

Table 1. Mean percent survivorship of two strains of crickets fed three diets.*

Diet	F_1 N	*G. rubens* Mean %	F_{11} N	*G. rubens* Mean %
Dog Chow	250	20.8[a]	222	4.5[a]
Refrigerated Cricket Chow	250	56.8[b]	222	6.8[a]
Freezer-stored Cricket Chow	250	58.0[b]	222	18.9[b]

*Means in the same column that have the same letter are not significantly different ($P > 0.05$) using Fisher's Protected LSD test.

An ANOVA indicated significant differences between survivorship of the two strains ($Pr > F = .0001$) as well as significant differences between diets within strains ($Pr > F = .0001$). Therefore each strain was analyzed independently using Fisher's Protected LSD to test for significant differences between diets.

F_1 lab-reared crickets had a higher survivorship on all diets than F_{11} lab-reared crickets. Significant differences between diets were not the same between strains. F_1 crickets survived well on refrigerator- and freezer-stored Cricket Chow but not on Dog Chow; F_{11} crickets did poorly on freezer-stored Cricket Chow and still worse on refrigerator-stored Cricket

Chow or Dog Chow.

F_1 crickets were also compared in terms of rate of development. Crickets reared on Dog Chow were slower to mature and more variable in maturation time than those on the other two diets (Fig. 2). While 74-79% of the crickets reared on refrigerator- and freezer-stored Cricket Chow matured during weeks 13-15, only 13% of the crickets reared on Dog Chow had matured through week 15 and the greatest percent maturing during a 3-week period was 51% (wks 16-18). For F_{11} crickets reared on freezer-stored Cricket Chow, the pattern of development was similar to F_1 crickets reared on that diet (too few F_{11} crickets survived on the other diets to be considered here).

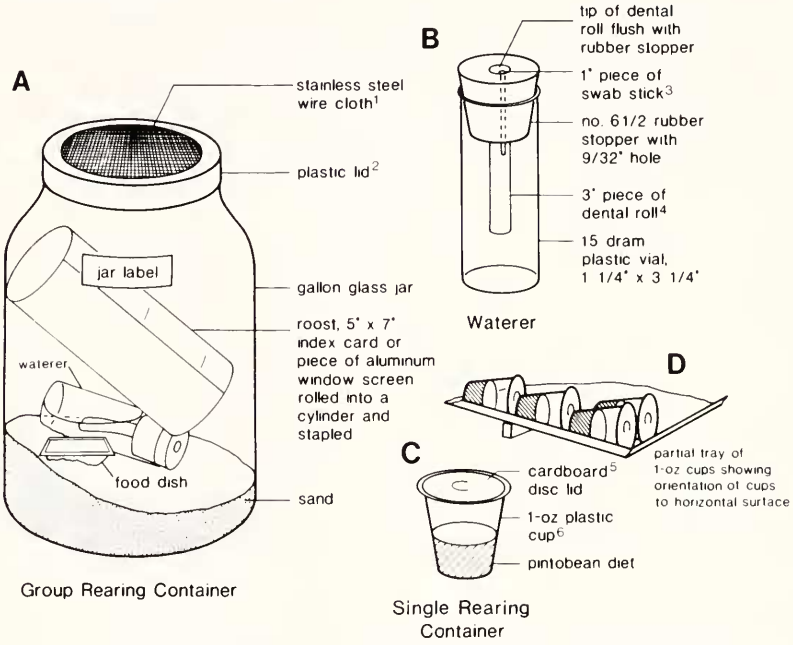

Fig. 1. A. Group rearing container. B. Waterer. C. Single rearing container. D. Holding tray. (1" = 2.54 cm) Notes (referenced by superscript numbers): (1) Stainless steel wire cloth, 60 mesh/inch, .0075" dia wire, .0092" width of opening, 30.5% open area. McNichols Co., 5501 Gray St., Tampa, FL 33609. [Wire window screen can be substituted, but it will admit ants and small spiders.] (2) 4¾ O.D. plastic lid, Dynalab Corp., P.O. Box 112, Rochester, NY 14692. (3) Piece of swab stick prevents vacuum from forming and causing the exposed tip of dental roll to become dry. (4) No. 2 (⅜" dia), 6-inch dental roll. Johnson and Johnson, New Brunswick, NJ 08903. Hand-rolled cotton or cloth might work. (5) Cardboard disc lid, 1.476"dia, no wax, no staples, pull tab. Standard Cap and Seal Co., P.O. Box 1766, Norton, GA 30091. (6) #410 clear plastic cup. Fill-Rite Inc., 49-55 Liberty St., Newark, NJ 07102.

These experimental results confirm what our previous data had suggested: that today's Purina Dog Chow is a poor diet for rearing *Gryllus rubens* especially in later laboratory generations, and that Purina Cricket Chow is a good diet. Moreover, the F_{11} lab-reared crickets were more sensitive to the effects of long-term storage of Cricket Chow than the F_1 crickets. Freezer-stored Chow apparently maintained its nutritional quality better than refrigerator-stored Chow.

Single Rearing

Rearing large numbers of crickets, one per gallon jar, would be inefficient and require a great deal of space. Therefore a method used to singly rear cabbage loopers (*Trichoplusia ni*) at the Insect Attractants, Behavior, and Basic Biology Research Laboratory, ARS-USDA, Gainesville, Florida (Guy, *et al.* 1985), was tested on *Gryllus rubens.* It worked well and required little space or labor.

Each newly hatched cricket that is to be reared is transferred, using a short-handled plastic teaspoon, to a one-ounce (15 ml) plastic cup (Fig. 1C) one-third to half-full of pintobean diet, a semi-soft solid diet (Guy *et al.* 1985). The cup is then closed with a tightly fitting cardboard lid and placed on its side in a tray. The tray is elevated on one end so that the end of the cup containing the diet is elevated (Fig. 1D). This allows wastes to roll to the other end and keeps the diet fresher. A 23 x 31 cm tray accommodates 28 cups.

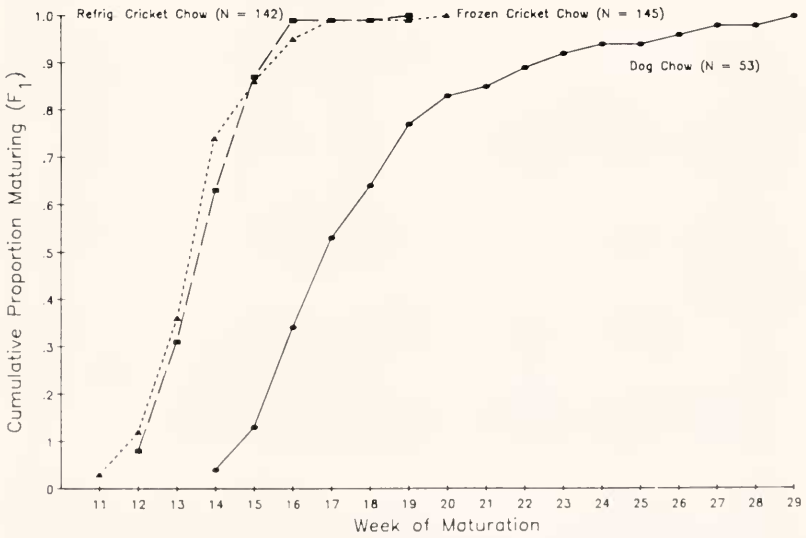

Fig. 2. Cumulative proportion of F_1 *G. rubens* maturing weekly on three diets.

Crickets live in these containers, held at 25±1°C and 70% R.H., for approximately three weeks with very little mortality. During this time, as moisture from the diet gradually escapes through the lid, the diet becomes drier. After three weeks, the diet is either too dry for the crickets to eat and/or the humidity of the container is too low and mortality increases. Therefore, crickets are transferred to new containers every three weeks. Transfers continue until the crickets reach maturity. At 25±1°C, 70% RH, 16L:8D, crickets require 4-6 transfers to reach maturity.

We do not know if this diet will sustain generations of crickets, but our singly reared crickets produced many progeny when allowed to mate and oviposit in one-gallon jars. Singly reared crickets were healthy and similar in size to field collected and first generation group-reared crickets. Of 27 cohorts of crickets (1 cohort = 25-78 hatchlings), representing 2 genetic strains, 2 inter-strain crosses, and 7 time periods, survival was never less than 50% and was ≥ 70%, 75% of the time.

DISCUSSION

Our problems with Dog Chow illustrate dangers in using commercial pet foods for rearing crickets. Unannounced changes in the formulas of pet foods may mean that successive batches of the "same" food may not be nutritionally equivalent. In addition, a formula that works well initially may prove inadequate after a few laboratory generations.

One solution to possible dietary problems in group-reared crickets is to develop a simple, user-controlled, nutritionally adequate diet. Because the pintobean diet met these criteria for singly reared crickets, we tried feeding pieces of fresh diet transferred directly from 1-oz. cups. This failed because very young crickets became trapped in beads of moisture that formed on the diet and died. (This rarely occurred in 1-oz. cups). We then tried drying the diet and grinding the pellets in a food mill. In preliminary tests, dried pintobean diet gave encouraging results, but longer and more extensive tests are needed. A cricket diet prepared and tested by Gardiner (1981) is also a candidate.

The group rearing methods described here are for modest numbers of crickets — the most that can be reared in a gallon jar is about 60. For economically rearing larger numbers, larger containers, such as garbage cans or large aquaria, should be used (see Appendix A).

In preparing this paper we circulated a draft to other researchers who rear crickets and invited them to submit notes and helpful hints on cricket rearing. Their responses were generous and touched on many aspects that we had not considered. Their comments are summarized in Appendix A and include information on rearing species in the following genera: *Acheta, Dianemobius, Gryllodes, Gryllus, Scapsipedus,* and *Teleogryllus.*

When we reviewed the literature, we found no comprehensive account of group or single rearing of field crickets; however, we did find three articles in which noteworthy techniques and diets are described. These articles are summarized in Appendix B and include information on rearing species in these genera: *Acheta, Gryllotalpa, Gryllodes, Gryllus, Mogoplistes, Nemobius, Plebeiogryllus,* and *Teleogryllus.*

Appendix A. Comments from other cricket-rearers.

1. T. Weber and F. Huber, Max-Planck-Institut für Verhaltensphysiologie, Seewiesen, W. Germany, rear eight species of crickets: *Gryllus campestris, G. bimaculatus, G.* sp. (from Argentina), *Acheta domesticus, Teleogryllus commodus, T. oceanicus, Scapsipedus marginatus,* and *Gryllodes supplicans.*

G. campestris is reared in a greenhouse under ambient conditions (natural photoperiod and near natural temperature; relative humidity about 60%) except in winter when the light cycle is artificially prolonged to 12 hours, the temperature is elevated to 24°C and moisture is added to maintain 60% R.H.

Outdoors, *G. campestris* produces one generation per year and overwinters in the penultimate instar. Under the greenhouse conditions, diapause is reduced to two months. However, females maturing under these conditions seem to lay fewer eggs and produce weaker offspring. Furthermore, the hemolymph is more fluid, and the animals do not survive as long under electrophysiological preparations as freshly caught ones. Therefore, nymphs are collected every fall and bred for one generation only.

Young *G. campestris* nymphs are housed in plastic aquaria — 25 x 50 x 30 cm (l x w x h) — with a screen cover. Because older nymphs are aggressive and may be injured by fighting, the last instars are isolated in 800 ml glass jars until maturity. For breeding, 5-6 males and females are placed in an aquarium.

Other species of crickets are kept in climate-controlled rooms, at 24 or 26°C, 12L:12D, and 60% RH. Molting success is better at higher humidity, but mites are worse.

About 30-50 adult crickets are kept in one plastic aquarium. More nymphs, depending on their size, are maintained in one aquarium. The floor of the aquarium is covered with 1 cm of sterlized sand (heated to 100°C for 1 hour). Three to four egg cartons, sterilized in the same way, are added as hiding places. Food is supplied in 8 cm dia shallow dishes. Every two days the back wall of the aquarium is sprayed with water. Molting crickets prefer this area. Additional water is supplied by a bird-cage waterer.

Eggs are laid in dishes filled with 4 parts peat and 1 part sand (sterilized as above), kept slightly moist by spraying with water. Dishes with eggs are covered with a transparent plastic cover and put in an incubator at 30°C until the first nymphs appear. Then they are returned to aquaria provided with special lighting — two parallel "fluorescent" lamps with a 12L:12D cycle (1 Osram daylight lamp L 65 watt/19 de Luxe and 1 Osram L Flora 65 Watt/77 R; the latter, normally used for growing plants, provides some UV light). This light program was instituted because *G. bimaculatus* looked pale after two generations. With this special lighting their pigmentation remains more natural.

When nymphs are in the first and second instars and difficult to collect, the aquaria are cleaned and the contents changed every four weeks. Otherwise, aquaria are cleaned every three weeks to prevent infestations of mites.

All crickets are fed a laboratory prepared diet as reported by Weber *et al.* (1981). Additional ingredients may be added such as dry fish-powder and pupae of flies or ants. Food is replenished every 2-3 days. Lettuce, washed 3 times by soaking in water for 30 minutes, is provided daily; the outer leaves are removed to prevent contamination by pesticides. Excess lettuce is given to provide humid places for the crickets. Pieces of carrots and apples are also provided daily.

2. D.B. Weissman, California Academy of Sciences, San Francisco, California, has raised all species of western U.S. *Gryllus* in small numbers. Females oviposit into 20 mm deep petri dishes filled with sterile sand that is watered every few days and "topped off" as the female digs around. After 1-2 weeks, the top layer of sand and associated droppings are removed and the dish is covered and kept at room temperature (21-26°C). The humidity is high and the eggs do well. Eggs hatch in 17-21 days and nymphs are then transferred to a 20 mm deep covered petri dish where the humidity can be kept high for the first few molts. They are fed rolled oats, Purina Cat Chow®, and pesticide-free Romaine lettuce (a source of protein as well as water). Damp filter paper provides moisture and a molting surface.

3. G. Tschuch, Martin-Luther-Universitat, Domplatz, E. Germany, rears *Gryllus bimaculatus* on dry sand at 28°C, 12L:12D with dishes of moist sand, 30 mm x 60 mm (h x dia) provided for egg-laying. Crickets are fed a diet of equal parts of soya flour, wheaten flour, bruised wheat, rolled oats, and powdered milk. Lettuce (stored in a deep freezer) is provided weekly. Without lettuce, sexual maturity of the imago is delayed. A bird waterer provides additional water.

4. H.W. Honegger. Technische Universität München, Garching, W. Germany, rears *Gryllus campestris.* Adults are aggressive and are housed separately in jars, 10 cm x 8 cm (h x dia), on a layer of dried peat. For breeding, females are transferred into jars with males. After mating, females are put singly overnight in jars two-thirds full of wet sand. Copulation is repeated with different males every second day for 10-14 days. Each female is allowed to lay eggs nightly for 14 days. The egg jars are then transferred to plastic aquaria, 45 x 24 x 26 cm. Nymphs move from an egg jar to the aquarium via a strip of paper. The stirp is bent over the rim of the jar — one end is jammed into the sand of the jar, the other end touches the aquarium floor.

At 26°C and 60-70% RH eggs start to hatch in about 21 days. When the population reaches 100-200 individuals, the egg-jars are removed and placed in a new aquarium. Crickets are fed a mixture of oatmeal, dried fish food (Tetramin) and dried bird food; the latter contains small ground-up insects and ant pupae. They are also fed organically grown lettuce 5 times per week, the only source of water provided. Old leaves are not removed unless they rot or become moldy. About 2-3 weeks after the first eggs hatch, a layer of dried peat is put into the aquarium.

Crickets take five months to develop from egg to adult at 26°C. As the juveniles grow, they are transferred into larger containers with smooth walls to prevent escape. A second generation can be reared over the winter, although it is difficult to get the adults to breed then.

Honegger notes the following pecularities of rearing *G. campestris.* The penultimate instar becomes quiescent for about a month, showing no signs of further development although fed. At least 20 pairs of crickets have to be mixed to prevent inbreeding. If only a few adults are used there are F_1 infertile individuals. Full siblings do not produce offspring even though mating seems to be successful (attachment of a spermatophore at the female's genital opening). Even under good rearing conditions, females reared in the lab differ slightly from those in the field; they have, for example, narrower heads.

5. S. Masaki, Hirosaki University, Hirosaki, Japan, notes that rearing nemobiine crickets economizes on space. About 70 can be reared in a 2 liter jar. A vial filled with water and plugged with cotton provides water as well as an oviposition site. Crickets are fed "Insect Feed," which consists of pellets of a mixture of powdered dry fish and corn meal. His laboratory has maintained a culture of *Dianemobius fascipes* from the Island of Ishigaki for more than 14 years.

6. R. Hoy and D.D. Yager, Cornell University, New York, rear *Teleogryllus oceanicus, T. commodus, Scapsipedus marginatus* and four species of *Gryllus.* A high priority is producing 50-100 virgin females of *T. oceanicus* every 2-3 weeks. Crickets are reared in 33 gal garbage cans at 27-29°C, 50-60% RH and 14L:10D. No "ground-like" substrate is used. Shelter and roosting places are provided by filling cans at least half-full with loosely crumpled paper towels (sometimes less depending on size of crickets). When eggs are needed, a deep dish filled with

moist peat moss or dark potting soil is introduced. The size of the next generation is controlled by limiting access to the egg dish or by limiting the number of hatching days.

Fine netting over the ventilation holes in the garbage can lids controls larger vermin. Occasional blooms of mites (*Tyrophagus* spp.) and booklice are controlled by extra cleaning and alcohol swabbing of the cans.

Crickets are fed Purina Cat Chow®. Water is provided by a vial filled with water and plugged with cotton. There has been some difficulty in rearing *G. rubens*. Two stocks died out gradually. They did well for 8-15 generations, then their fertility declined.

T. oceanicus is sometimes reared individually in petri dishes with no special food, substrate or water. Eggs require 18-20 days to hatch, nymphs require 7-10 weeks to reach maturity, and adults live for about 8 weeks.

7. V.R. Vickery, Macdonald College, McGill University, Ste. Anne de Bellevue, Quebec, uses aquaria for rearing large numbers of crickets. Mated females are kept in jars provided with sand-filled petri dishes. For species that require winter diapause, these space-efficient dishes are stored at +4°C for six or more weeks, and at times, up to 10 months before allowing hatching at room temperature.

8. K.H. Hoffmann, Universitat Ulm, Ulm, Federal Republic of Germany, has maintained a stock of *Gryllus bimaculatus* for two years. Crickets are kept according to stage in large plastic-tanks. IR-breeding lamps provide constant light. Temperature is maintained at 32°C. No mold occurs. Animals are fed minced Altromin 2023 standard diet (for rabbits and rats) and water. Egg-dividers provide hideouts for the crickets.

Temperature and % of protein in the diet affect the growth of *G. bimaculatus* (Merkel 1977). Nymphs allowed to bask in "sunshine" at self-determined intervals have reduced development times (Behrens *et al.* 1983 and Remmert 1985).

Appendix B. Notes from pertinent articles.

1. Clifford, C.W., R.M. Roe, and J.P. Woodring. 1977. Rearing methods for obtaining house crickets, *Acheta domesticus,* of known age, sex, and instar. Ann. Entomol. Soc. Am. 70:69-74.

Clifford *et al.* present in detail a method of group rearing *Acheta domesticus* of known ages. They report 82% total survival from hatchling to adult with 100% survival after the second instar. Moreover their procedures seem time-efficient.

Of particular note is their use of 1-gallon compressed cardboard containers with screen-top lids for rearing 10-12 last instar crickets. The rim is fitted with a 2-3 cm piece of heavy aluminum foil to prevent crickets from crawling out. The lid center is replaced with window screening for ventilation. The cardboard surface provides floor (192 cm^2) and wall space (574 cm^2) for crickets to rest on eliminating the need for a perch. A petri dish with masking tape on the outside wall for easy climbing is used to hold the food. Water is supplied by a plastic vial with two holes cut along the rim, filled and inverted into a petri dish, similarly rimmed with masking tape. This setup will sustain crickets for at least eight days. They report cardboard containers can withstand frequent washings and will last several months.

2. Mathad, S.B., and K. Dakshayani. 1972. Laboratory rearing of the cricket *Plebeiogryllus guttiventris.* Ann. Entomol. Soc. Am. 65:282-283.

Mathad and Dakshayani are the first to report rearing this species in the lab. They experimented with various diets and temperatures and reported that guinea pig diet and 35°C gave high survival and short duration of the nymphal stage.

3. Gardiner, B.O.C. 1981. Rearing crickets. Bull. Amat. Entomol. Soc. 40:132-143.

Gardiner presents a table of 5 diet formulations used by researchers for crickets and rearing notes on these species: *Acheta configuratus, Gryllotalpa gryllotalpa, Gryllodes sigillatus, Gryllus campestris, G. bimaculatus, Mogoplistes squamiger, Nemobius sylvestris, Plebeiogryllus guttiventris,* and *Teleogryllus* sp.

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